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NEW FORMULATION FOR THE VISCOSITY OF NORMAL BUTANE

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The exact knowledge of thermophysical properties of fluids with industrial importance is required for a more accurate basic design of compressors, gas turbines, and gas pipelines as well as cooling cycles and chemical processes. In contrast to the thermodynamic properties, the transport properties of normal butane, particularly in the region near to the critical point, are not sufficiently well-known. The current NIST standard database REFPROP 9.1 of Lemmon et al. (2013) recommends the viscosity correlation of Vogel et al. (1999), which is characterized by standard uncertainties of up to 3% in its range of validity applying an outdated equation of state of Younglove and Ely from 1987. Due to the fact that REFPROP 9.1 approves the reference equation of state of Bückner and Wagner (2006) for the thermodynamic properties of normal butane, there is a basic necessity for developing a new viscosity formulation for this working fluid.

Recently, very accurate viscosity measurements were performed by Herrmann and Vogel (2015) using a vibrating-wire viscometer in combination with a single-sinker densimeter. The standard uncertainty of these data was conservatively estimated to be 0.3%. Hence, they are considered to be primary data. In addition, viscosity measurements by Küchenmeister and Vogel (1998), whose results have already been used by Vogel et al. (1999) when generating their correlation, were re-evaluated (2017), so that they are qualified for being primary data, too.

Applying the new reference equation of state of Bückner and Wagner (2006) together with the improved data situation in the dense-gas region, a new viscosity formulation for normal butane was generated using the structure-optimisation method by Setzmann and Wagner (1989). The new formulation concept incorporates four contributions concerning the zero-density viscosity, the initial-density dependence, the near-critical region, and the higher-density terms of the residual viscosity. The first two contributions are completely treated separately using little support of the kinetic theory. The critical-enhancement terms related to the near-critical region were slightly pre-treated with respect to the choice of some parameters. At the end, the bank of terms needed in the optimization procedure comprises only terms for the near-critical region and for the higher-density contribution. The latter terms are composed of a combination of double polynomials in the reduced density and reciprocal reduced temperature, some of them combined with a negative exponential function of the reduced density. The validity range of the new formulation extends from the melting line to temperatures of 650 K and to pressures of 100 MPa. The extrapolation and consistency behaviours of the formulation were investigated. Values calculated for the new viscosity formulation were compared with the primary data, used when developing the formulation, and with values resulting from the earlier viscosity correlations of Vogel et al. (1999) and of Quiñones-Cisneros and Deiters (2006).